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Correcting Late Cenozoic Sea-Level Records for Dynamic Topography: Examples from Australia

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Much of our understanding of ice sheet sensitivity to climatic forcing is derived from palaeoshoreline records of past sea-level. However, the present-day elevations of these sea-level markers reflect the integrated effect of both ice volume change and solid Earth processes. Accurately quantifying the latter contribution is therefore essential for making reliable inferences of past ice volume. While uncertainties associated with glacial isostatic adjustment (GIA) can be mitigated by focusing on sites far from ice sheets, the same is not true for mantle flow-driven dynamic topography, which is ubiquitous and can generate vertical motions of ~±100 m on million-year timescales. As a result, improved knowledge of the spatio-temporal evolution of this transient topography is required to refine constraints on ice sheet stability and to guide modelling of future trajectories.

Since the shortest wavelength and fastest evolving contributions to dynamic topography originate in the shallow mantle, reconstructing dynamic topography over 1–10 Myr timescales requires accurate models of Earth's lithosphere and asthenosphere. Here, we construct these models by mapping upper mantle shear wave velocities from high-resolution surface wave tomographic models into thermomechanical structure using calibrated parameterisations of anelasticity at seismic frequency. Resulting numerical predictions of present-day dynamic topography are in good agreement with residual depth measurements, with particularly good fits obtained around Australia. In this region, predicted temperatures are also compatible with palaeogeotherms extracted from xenolith suites, indicating that present-day upper mantle structure is well characterised and that numerical "retrodictions" of vertical motions are more likely to be reliable. In addition, Australia is sufficiently distant from major ice sheets that uncertainty in GIA contributions to sea-level change are relatively small. These considerations, combined with new compilations of continent-wide sea-level indicators, make Australia a particularly promising location for separating out ice volume-driven global mean sea-level changes from local sea-level variations related to vertical land motions and gravitational effects.

By back-advecting density perturbations from an ensemble of Earth models, we demonstrate that ~±200 m relative sea-level changes across Australia since the Mid-Pliocene Warm Period (MPWP; □3 Ma) can be tied directly to changes in dynamic topography. Significantly, after removing this signal from observed relative sea-level changes, a consistent global mean sea-level during the MPWP of 12±8 m above present is obtained, towards the lower end of previous estimates.